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# The Effect of Negative and Positive Granularity on the Final Print Granularity

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# THE EFFECT OF NEGATIVE AND POSITIVE GRANULARITY ON THE FINAL PRINT GRANULARITY

Senior Research Project

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# ABSTRACT

Theoretically, the relation of negative and positive rms granularity to the final print granularity is described by the following equation:

$$\sigma(D)_{\text{print}} = \left[\sigma(D)^2_{\substack{\text{negative}\\\text{material}}} + \sigma(D)^2_{\substack{\text{positive}\\\text{material}}}\right]^{\frac{1}{2}}.$$

Using fine, medium and coarse grained positive and negative materials in a variety of printing situations, the validity of the above equation was tested. Results of this investigation indicated that the hypothesized equation does not hold for a variety of printing situations.

# INTRODUCTION

The appearance of inhomogeneity in a developed photographic emulsion as viewed by an observer is defined as graininess. Granularity designates the objective aspect of graininess in terms of spatial variations of density in the developed image.[1]

Doerner states that there are three methods of analyzing granularity.[2] One method is based on the use of a microdensitometer utilizing a sufficiently small scanning aperture to make numerous density readings on a uniformly exposed emulsion. The distribution of a large number of these density readings, 1000 or more, will be Gaussian. The standard deviation of the density readings from the mean density is the parameter used to describe granularity. Granularity of this type is also termed rms granularity due to the fact that one standard deviation, $\sigma(D)$, is defined as the root mean square of the deviations.[3]

It has been shown that granularity varies with density and the size of the scanning aperture. Specifically, granularity varies with the square root of density and is inversely proportional to the size of the aperture.[4,5] Therefore, these variables must be kept constant in order to achieve a standardized value for granularity. For example, Eastman Kodak reports rms granularity for unit density with a 24 micron diameter aperture.

There are two reasons why rms granularity has achieved success. First of all, it has a high degree of correlation with graininess.

Secondly, it is analogous to electronic noise.[6]

Another technique for analyzing granularity utilizes the auto-correlation function. This function characterizes granularity as a spatial measurement correlating the signal on a uniformly exposed emulsion by a given distance.[7,8]

The third method for analyzing granularity is called the Wiener spectrum. This is a relationship where signal (granularity) is a function of frequency.[9,10,11]

The advantage of the Wiener spectrum is [illegible] related to the transfer of granularity in a photographic system. To analyze print granularity, simple multiplication of the Wiener spectrums of the negative and positive materials will produce the Wiener spectrum of the final print.[12]

In reviewing the state of the art of granularity, a considerable amount has been written using the Wiener spectrum as a method of analyzing the granularity of a photographic system (negative and print), whereas little has been written relating the analysis of a photographic system to rms granularity.

Statistical theory, however, offers a relationship which can explain the effect of negative and positive granularity on the final print granularity. In general, the total standard deviation of a system, $\sigma_T$ , is equal to the square root of the sum of the individual variances, $\sigma_i^2$ :

$$\sigma_T = \left( \Sigma\, \sigma_i^2 \right)^{\frac{1}{2}} \qquad (1)$$

Applying equation (1) to a simple photographic system, an expression may be derived for the final print granularity:

$$\sigma(D)_{print} = \left[\sigma(D)^2_{\substack{negative\\material}} + \sigma(D)^2_{\substack{positive\\material}}\right]^{\frac{1}{2}} \qquad (2).$$

In a complex photographic system (more than two generations), the final print granularity may be calculated by appropriately adding the granularity of each generation to equation (2).

## OBJECTIVES

The purpose of this paper is to determine whether the relation of negative and positive granularity to the final print granularity will validate equation (2).

## EXPERIMENTAL PROCEDURE

The hypothesis was tested using fine, medium and coarse grained negative and positive materials following the experimental design shown in Figure 1. The design indicates the various types of printing situations used. Granularity values were then calculated for the positive and negative materials and also for the final prints. These calculations were made from microdensitometer traces of each of the samples. The hypothesis was then tested using these values.

### Production of Originals

The materials selected were Kodak High Definition Aerial Film- Type 3404, Kodak Plus-X Aerographic Film- Type 5401, and Kodak Tri-X Aerecon Film- Type 8403. These represented fine, medium and coarse grained emulsions respectively. Each film was exposed to three levels of uniform illumination in order to produce three

# EXPERIMENTAL DESIGN

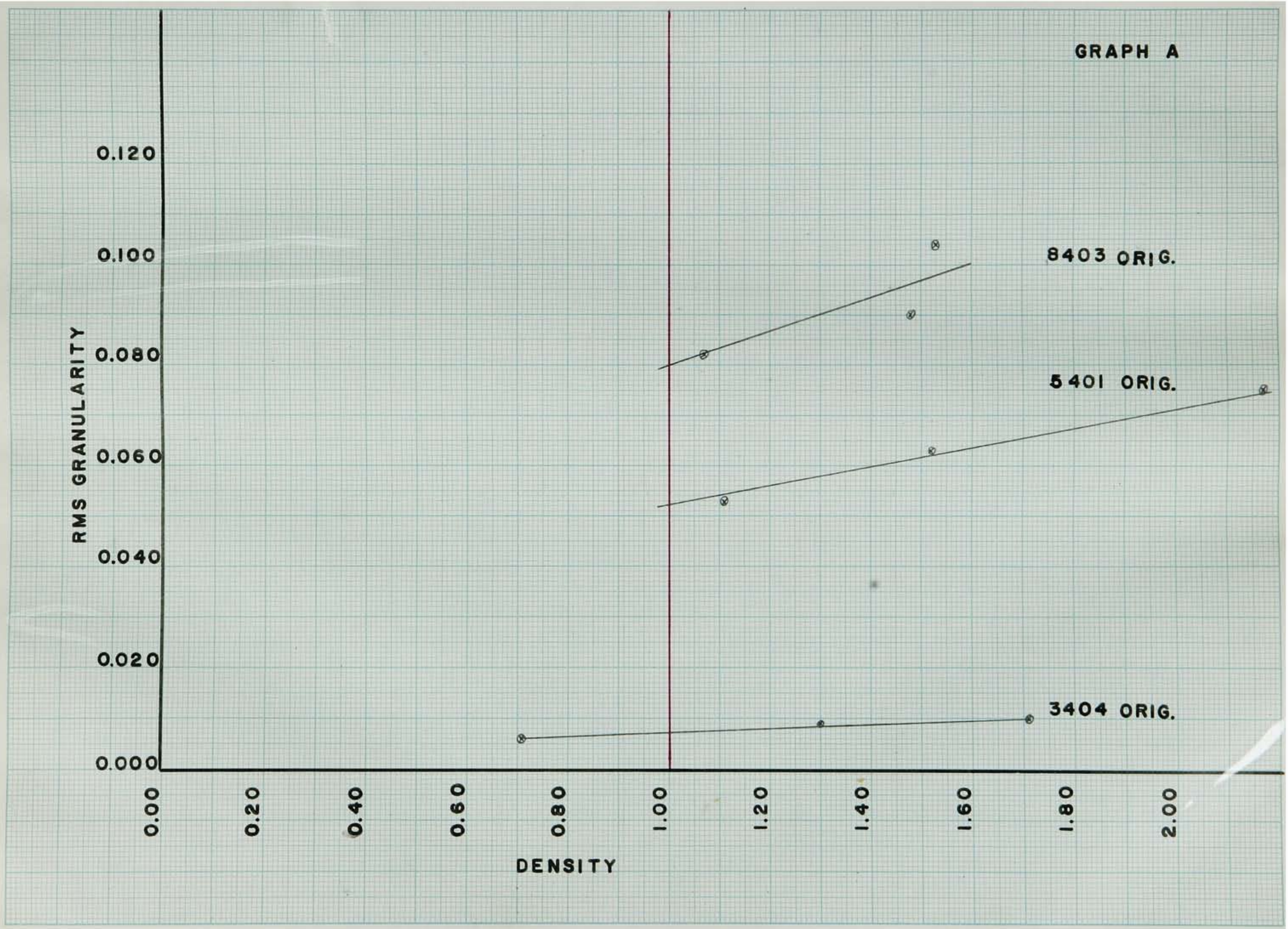
| | FILM TYPE 3404 NEGATIVE MATERIAL | FILM TYPE 5401 NEGATIVE MATERIAL | FILM TYPE 8403 NEGATIVE MATERIAL |
|---|---|---|---|
| FILM TYPE 3404 POSITIVE MATERIAL | TWO REPLICATED PRINTS | TWO REPLICATED PRINTS | TWO REPLICATED PRINTS |
| FILM TYPE 5401 POSITIVE MATERIAL | | TWO REPLICATED PRINTS | TWO REPLICATED PRINTS |
| FILM TYPE 8403 POSITIVE MATERIAL | | | TWO REPLICATED PRINTS |

FIGURE 1

densities. All exposures were made on a non-laminar flow work bench (see figures 2 and 3 in Appendix) in order to prevent dust from accumulating on the film during the exposure and being transferred to the prints. The processing of the original negatives as well as the prints was in D-19 @ 68° F for 8 minutes using ASA standard agitation. Granularity values were measured for these levels of density and then plotted as a function of density (Graph A). The granularity values obtained from this graph for the negative materials were also used as the granularity values for the positive materials in later calculations.

Production of Prints

The prints were made by exposing the original negatives on to the specific films designated by the experimental design. Exposures were made using essentially specular illumination in order to minimize the scattering of light within the original negative. The levels of illumination were selected on the basis that the densities of the original negatives were reproduced in the final prints within a tolerance of ±0.10. For the exposure, the original negative and the unexposed film were placed in a contact print frame and separated by tetrachloroethylene stabilized with ethanol. Good optical contact was maintained during exposure in order to assure even distribution of the fluid between the two films. By using tetrachloroethylene, which has an index of refraction approximately equal to that of gelatin, the scattering of light between the two materials during exposure was minimized. It was necessary for the tetrachloroethylene,

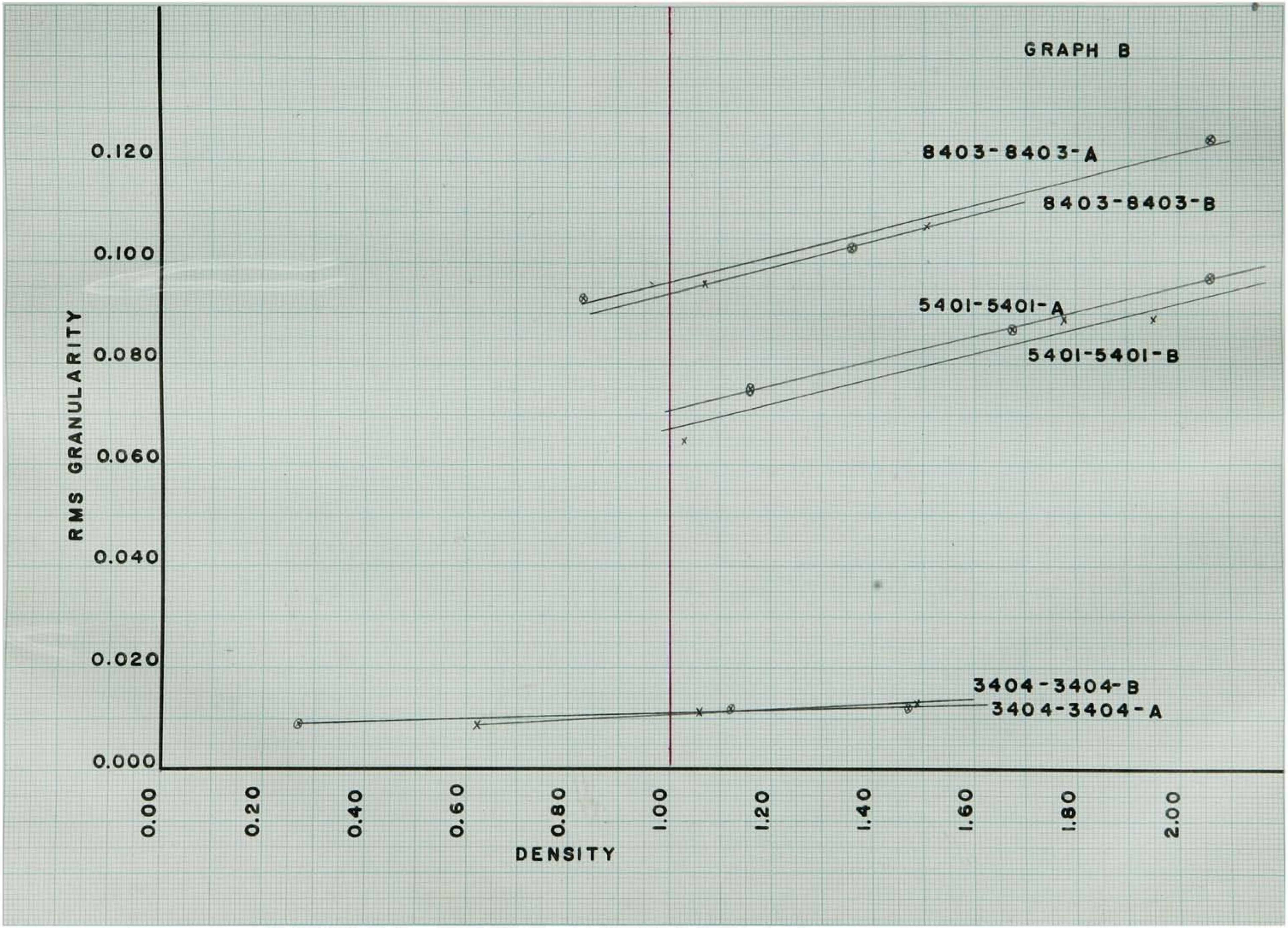

GRAPH A
8403 ORIG.
5401 ORIG.
3404 ORIG.
RMS GRANULARITY
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
DENSITY

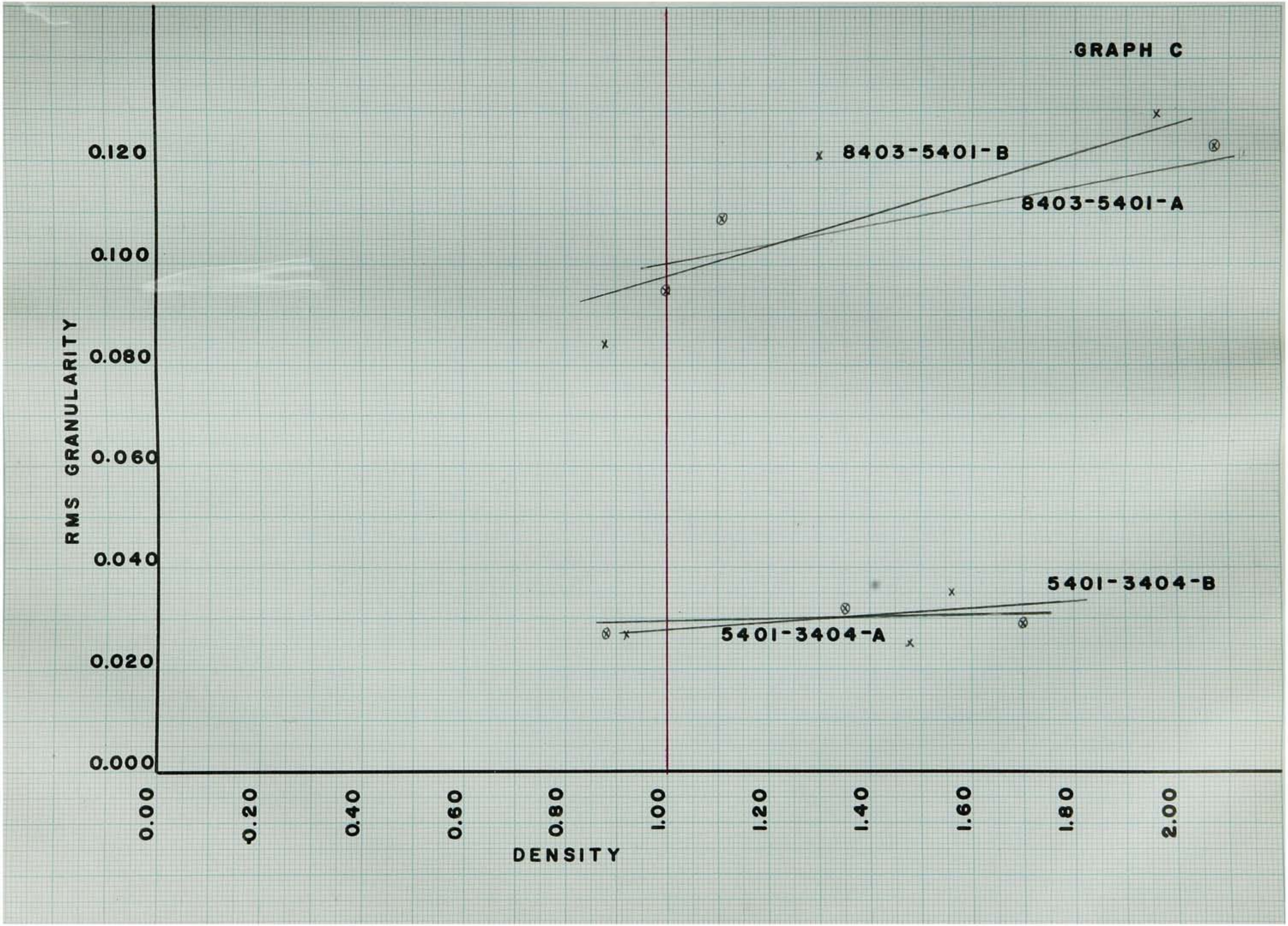
a highly volatile liquid, to be of high chemical purity in order to prevent a residue from remaining on the film after evaporation. The presence of residue on the exposed film produced a mottle on the final print during processing. From the final prints, granularity measurements were made and plotted as a function of density (Graphs B and C).

Granularity Measurement Procedure

In order to determine rms granularity, the procedure used by the Perkin-Elmer Corporation was employed. This procedure consisted of scanning a sample with the Perkin-Elmer Microdensitometer and evaluating its digital tape output on a Scientific Data Systems 9300 computer.

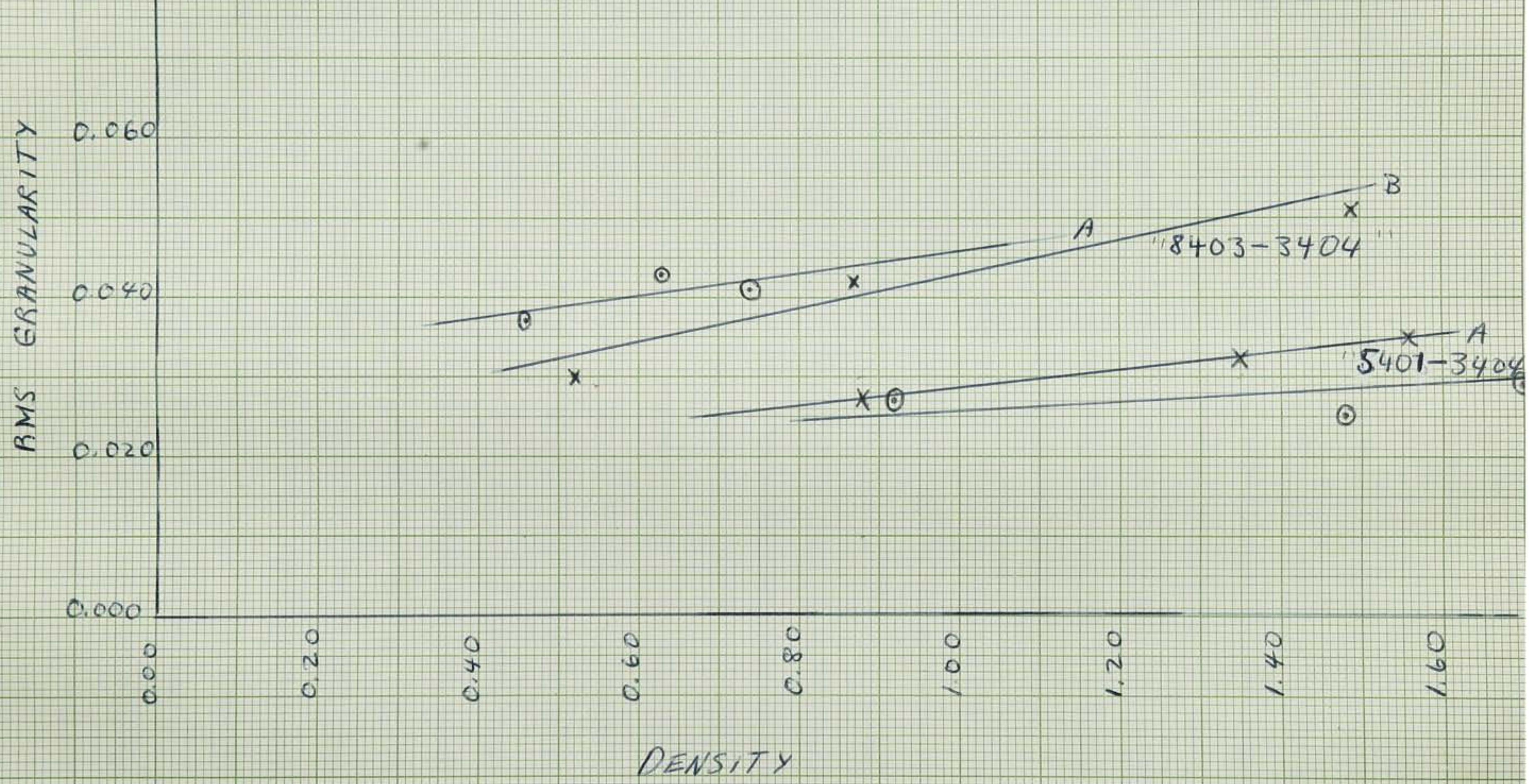
The optical system of the microdensitometer was composed of a source microscope objective with a numerical aperture of 0.25, a reading microscope objective with a numerical aperture of 0.30 and a 25X compensating eyepiece. As the sample was scanned with a circular aperture, amplifier voltages, which accurately corresponded to sample transmittances, were recorded on punch tape. The transmittance readings taken from the sample were made in such a manner that each was separated by a distance equal to or greater than the effective diameter of the circular scanning aperture. One thousand transmittance values were recorded in subsets of one hundred values. By using one thousand transmittance values, measurement errors were reduced to 4% or less. The microdensitometer focus was checked before recording each subset. Periodic refocusing was necessary because of the


GRAPH B
8403-8403-A
8403-8403-B
5401-5401-A
5401-5401-B
3404-3404-B
3404-3404-A
RMS GRANULARITY
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
DENSITY


GRAPH C
8403-5401-B
8403-5401-A
5401-3404-B
5401-3404-A
0.120
0.100
0.080
0.060
0.040
0.020
0.000
RMS GRANULARITY
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
DENSITY

# GRANULARITY-DENSITY CURVES

These data cannot be satisfactorily explained. The "8403-3404" are close to the calculated values for 5401-3404, but the 5401-3404 are much above the calculated and observed values of 3404-3404, so that it is not simply mixed samples. JHC 6/20/66



difficulty of positioning the emulsion surface parallel to the stage surface over the entire length of the scan.

The rms granularity for each film sample was then calculated by means of a computer program in the following manner: the first 100 transmittance values were converted into density values and the mean density was calculated and printed out in column A (see Figure 4). The variance and standard deviation for these values were then determined and printed out in colums B and C respectively. The standard deviation was then converted into the standard deviation value which would be obtained by a 24 micron diameter aperture and printed out in column D. All density values outside $\pm$ 2 standard deviations were then discarded in order to minimize the measurement errors due to emulsion imperfections or images of large dust particles. Using the remaining values, the above procedure was repeated and a corrected mean density, variance, standard deviation and standard deviation for a 24 micron diameter aperture were calculated and printed out in their respective columns. In addition, the number of densities removed from the original 100 values was printed out in column E. The above procedure was then repeated until 10 subsets had been completed. From this point on the computer used only the value of standard deviation appearing in the even rows (corrected values). The standard deviation of these 10 values was then calculated and all those outside $\pm$ 1 standard deviation were discarded. Column I indicates the number of subsets of 100 densities removed. Using the remaining values of standard deviations and their corres-

| SUBSET | COLUMN A MEAN DENS. | ROW | COLUMN B VAR. | COLUMN C STAND DEV. | COLUMN D SD-24MIC. | COLUMN E NØ. REMØVED |
|---|---|---|---|---|---|---|
| 1 | .11971E 01 | ODD | .24612E-01 | .15688E 00 | .87461E-01 | 0 |
| | .11922E 01 | EVEN | .20883E-01 | .14451E 00 | .80563E-01 | 3 |
| | MEAN DENS. | | VAR. | STAND DEV. | SD-24MIC. | NØ. REMØVED |
| 2 | .12157E 01 | | .26852E-01 | .16386E 00 | .91354E-01 | 0 |
| | .12089E 01 | | .18805E-01 | .13713E 00 | .76452E-01 | 8 |
| | MEAN DENS. | | VAR. | STAND DEV. | SD-24MIC. | NØ. REMØVED |
| 3 | .11849E 01 | | .31971E-01 | .17881E 00 | .99684E-01 | 0 |
| | .11704E 01 | | .21209E-01 | .14563E 00 | .81191E-01 | 2 |
| | MEAN DENS. | | VAR. | STAND DEV. | SD-24MIC. | NØ. REMØVED |
| 4 | .11696E 01 | | .21695E-01 | .14729E 00 | .82116E-01 | 0 |
| | .11658E 01 | | .16994E-01 | .13036E 00 | .72677E-01 | 5 |
| | MEAN DENS. | | VAR. | STAND DEV. | SD-24MIC. | NØ. REMØVED |
| 5 | .11346E 01 | | .24044E-01 | .15506E 00 | .86447E-01 | 0 |
| | .11348E 01 | | .22387E-01 | .14962E 00 | .83414E-01 | 2 |
| | MEAN DENS. | | VAR. | STAND DEV. | SD-24MIC. | NØ. REMØVED |
| 6 | .11559E 01 | | .20307E-01 | .14250E 00 | .79444E-01 | 0 |
| | .11478E 01 | | .16184E-01 | .12721E 00 | .70922E-01 | 4 |
| | MEAN DENS. | | VAR. | STAND DEV. | SD-24MIC. | NØ. REMØVED |
| 7 | .11727E 01 | | .31130E-01 | .17644E 00 | .98363E-01 | 0 |
| | .11804E 01 | | .23252E-01 | .15249E 00 | .85011E-01 | 6 |
| | MEAN DENS. | | VAR. | STAND DEV. | SD-24MIC. | NØ. REMØVED |
| 8 | .11308E 01 | | .20892E-01 | .14454E 00 | .80581E-01 | 0 |
| | .11317E 01 | | .16408E-01 | .12809E 00 | .71412E-01 | 4 |
| | MEAN DENS. | | VAR. | STAND DEV. | SD-24MIC. | NØ. REMØVED |
| 9 | .11067E 01 | | .21735E-01 | .14743E 00 | .82190E-01 | 0 |
| | .10999E 01 | | .17306E-01 | .13155E 00 | .73340E-01 | 4 |
| | MEAN DENS. | | VAR. | STAND DEV. | SD-24MIC. | NØ. REMØVED |
| 10 | .10969E 01 | | .20361E-01 | .14269E 00 | .79551E-01 | 0 |
| | .10930E 01 | | .15668E-01 | .12517E 00 | .69784E-01 | 3 |

SIGMA ØF THE SDS.
.10102E-01

| COLUMN F VARIANCE | SIGMA | SIGMA24MIC. | COLUMN I NØ. REMØVED |
|---|---|---|---|
| .18256E-01 | .13511E 00 | .75326E-01 | 3 |
| | COLUMN G | COLUMN H | |

COLUMN J
MEAN ØF MEAN DENS.
.11595E 01

SAMPLE OF COMPUTER PRINT-OUT SHEET

FIGURE 4

ponding variances and mean densities, the total values of mean variance and mean density for the film sample were calculated and printed out in colums F and J. The standard deviation and the standard deviation for a 24 micron diameter aperture were then calculated from the value of mean variance and printed out in columns G and H. The value in column H is taken as the rms granularity for a film sample having a mean density printed in column J.

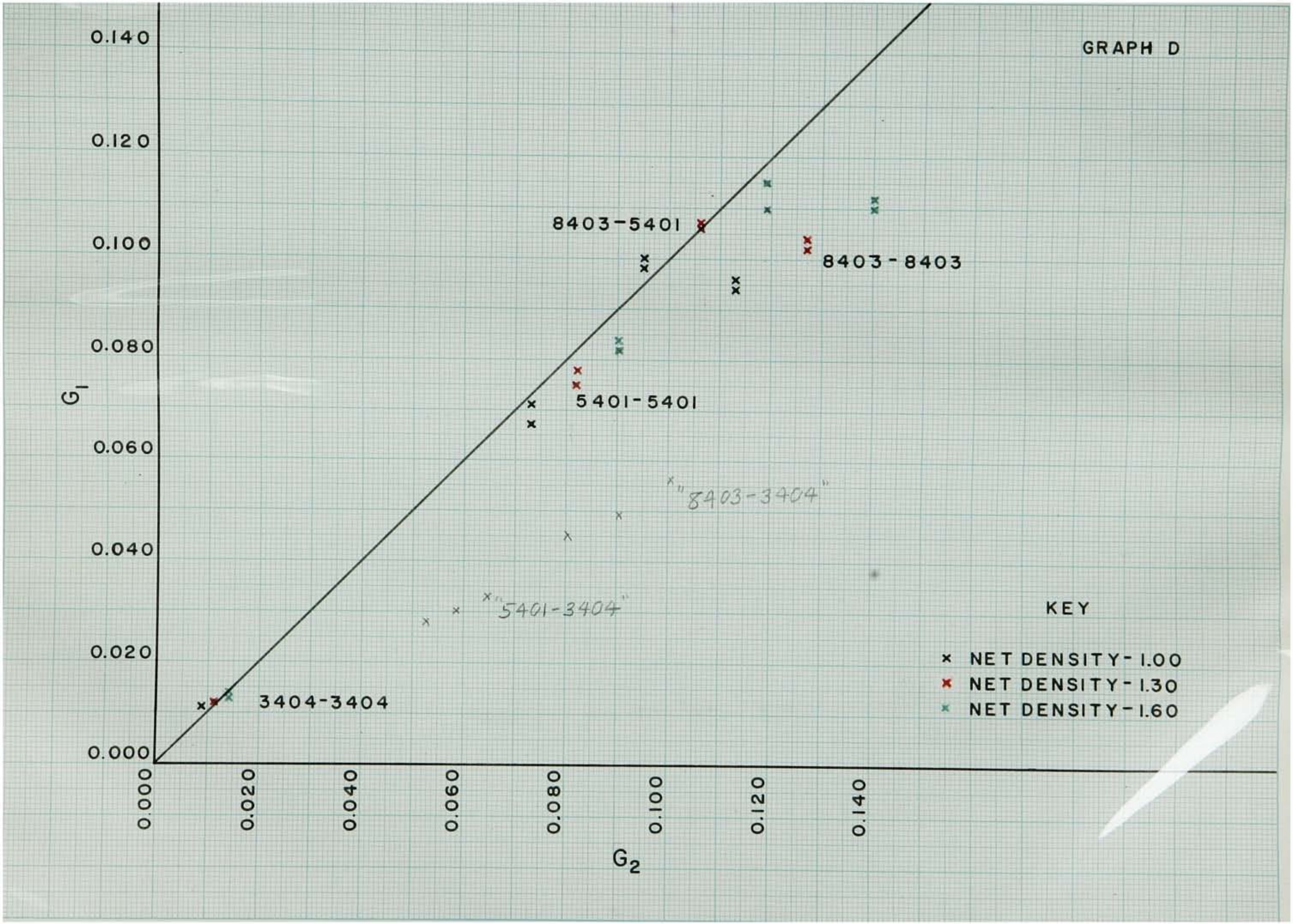
## RESULTS

Graphs A, B and C represent granularity values obtained from the original negatives and the final prints. The data for the prints of 8403 on 3404 (not plotted) and 5401 on 3404 were found to be completely erroneous, and therefore not used in the final analysis. This data was discarded on the basis that the granularity of the print should be higher than that of the original negative. The granularities for these prints, however, were lower than their original negatives.

These data have been inserted in the report, and indicated, with question marks in graph D
BHC 6/24/66

Granularity values at density levels of 1.00, 1.30 and 1.60 were taken from graphs A, B and C. These values were then used to test the hypothesis, equation (2), and the resulting data was plotted on Graph D. The axes on Graph D, $G_1$ and $G_2$, represent the value of granularity for the final print, $\sigma(D)_{print}$, and the expected granularity for the final print,

$$\left[ \sigma(D)^2_{\substack{\text{negative}\\ \text{material}}} + \sigma(D)^2_{\substack{\text{positive}\\ \text{material}}} \right]^{\frac{1}{2}} .$$


GRAPH D
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
$G_1$
0.000
0.020
0.040
0.060
0.080
0.100
0.120
0.140
$G_2$
8403-5401
8403-8403
5401-5401
"8403-3404"
"5401-3404"
3404-3404
KEY
NET DENSITY - 1.00
NET DENSITY - 1.30
NET DENSITY - 1.60

Two Chi-Square goodness of fit tests were applied to the data on Graph D. For the first test, different printing situations were used as the variable, and for the second, different density levels. Both tests used an alpha risk of 0.01. The first test resulted in lack of fit being significant, thus rejecting the hypothesis. The second test resulted in lack of fit being not significant. This indicated that density was not a factor in rejecting the hypothesis.

## CONCLUSION

The effect of negative and positive granularity on the final print granularity cannot be described by equation (2) with respect to the printing situations described in the experimental procedure. The probability still remains that the hypothesis can be applied to some particular printing situation. It is of greater significance, however, that the hypothesis does not hold over all printing situations. Consequently, equation (2) is not an accurate description for the transfer of granularity through all photographic systems.

## ACKNOWLEDGEMENTS

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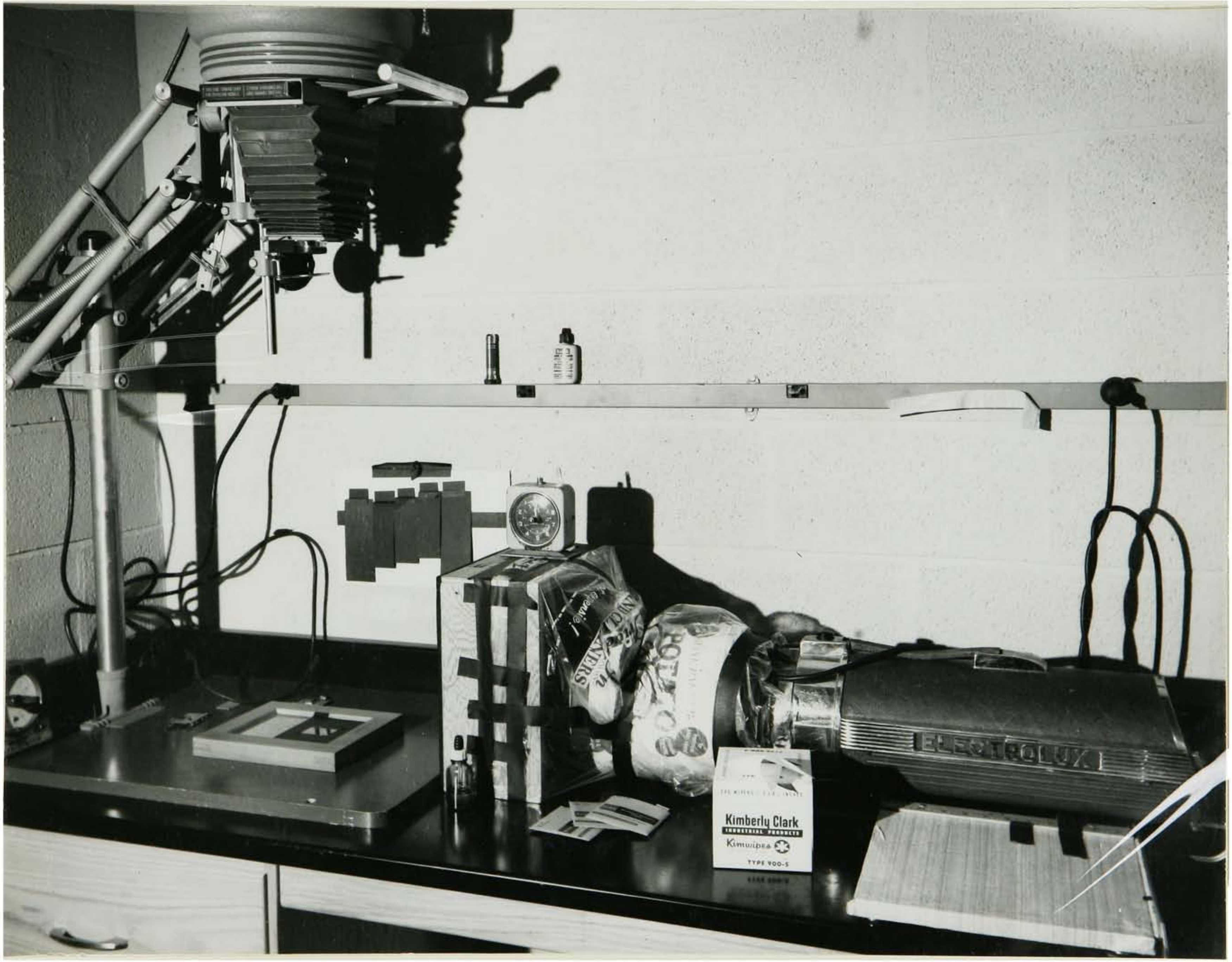
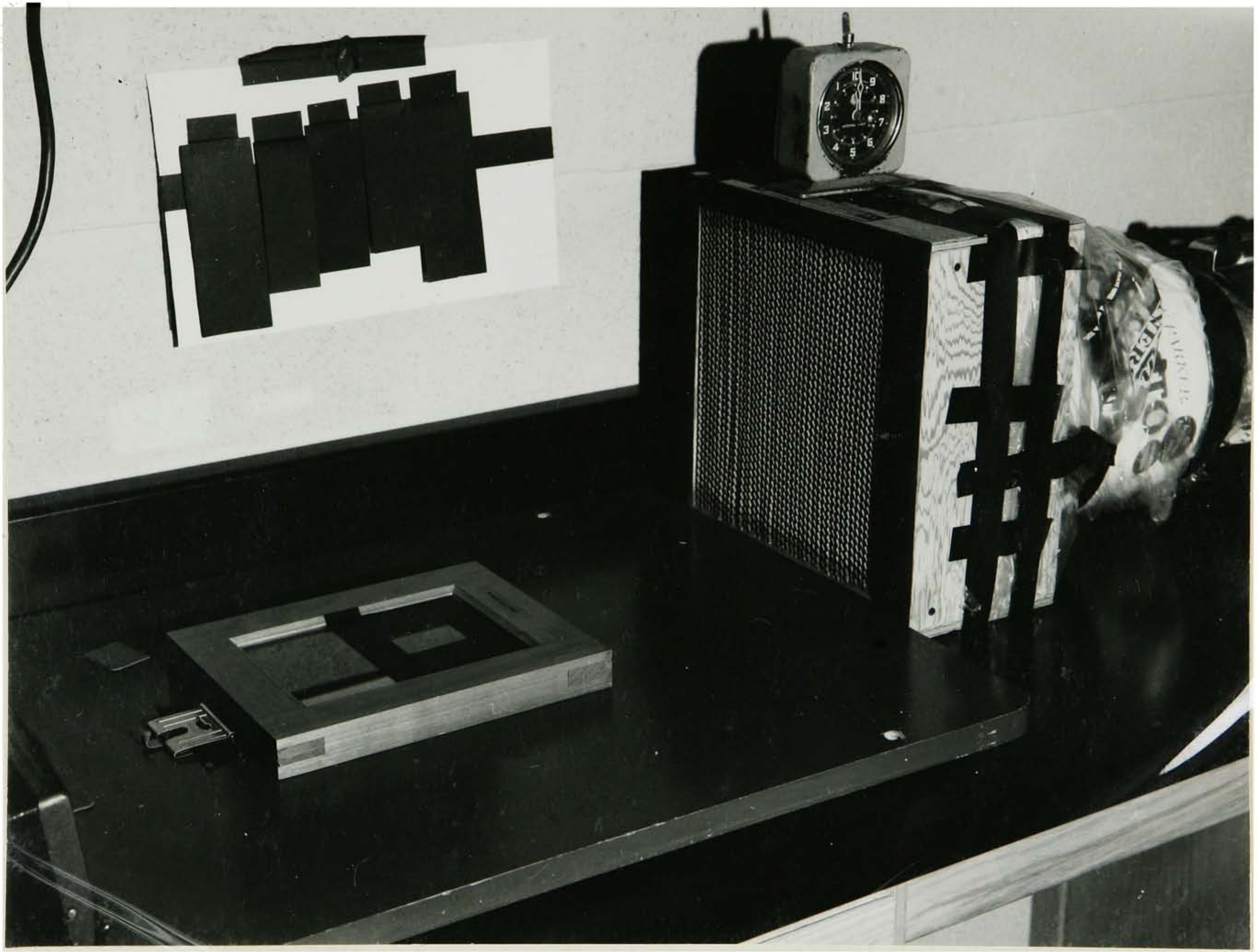
# A P P E N D I X




NON-LAMINAR FLOW WORKBENCH FIGURE 2



CLOSE-UP VIEW OF PRINT FRAME & ABSOLUTE FILTER FIGURE 3

FOOTNOTES

1. T.H. James and G.C. Higgins, <u>Fundamentals of Photographic Theory</u> (Morgan and Morgan, New York, 1960), pp. 268-269.

2. E.C. Doerner, JOSA 6, 669 (1962).

3. J.H. Altman, Applied Optics 3, 35 (1964).

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10. Altman, op. cit.

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12. Doerner, op. cit.

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